ASE Parasitics
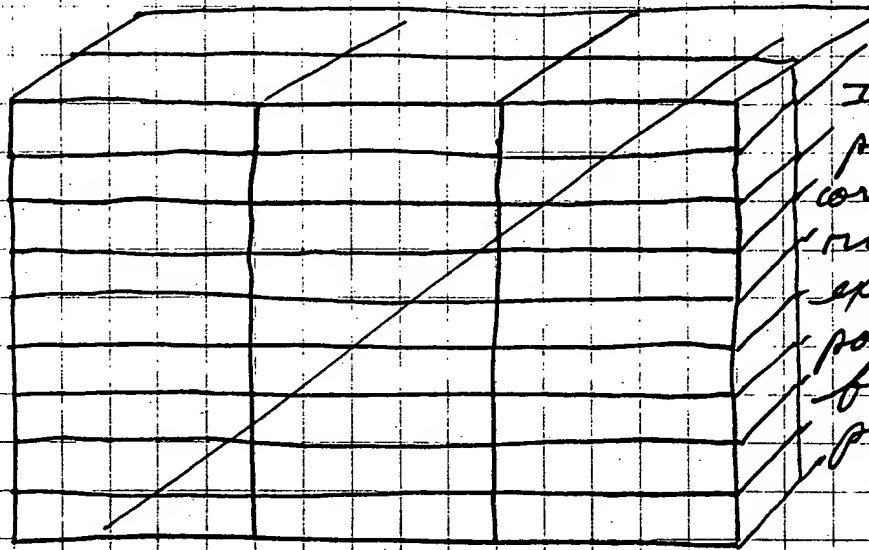3-Sep-97

In this latte
picture a para
corresponds to o
ray ending up
exactly n latt
position removed
from its origin
position.

① pick a direction vector
② calculate reflection off 3 sets of orthogonal plane
③ calculate travel distance between successf
hits on a single set of planes
④ assign a loss/ime number

This looks amenable to an analytic
~~treatment~~

5-Sep-97
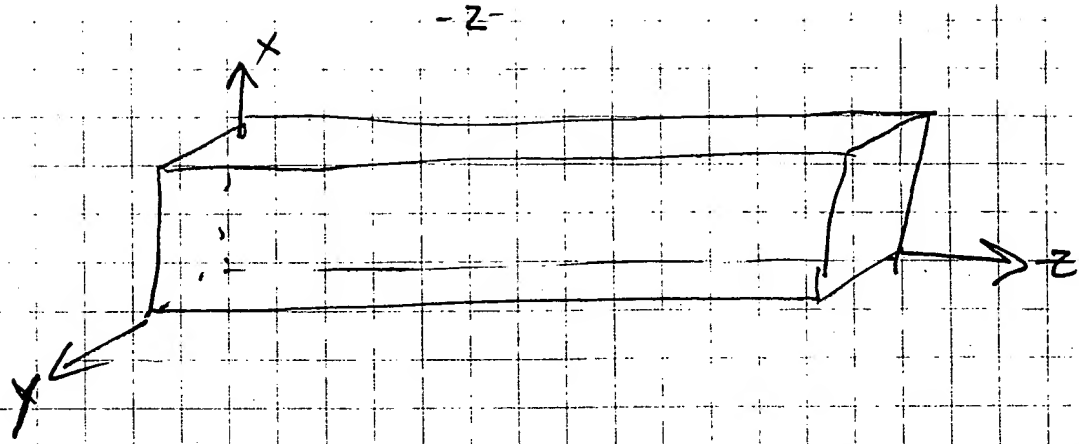
use direction cosines to parameterize ray direction

$$(\cos\theta_x, \cos\theta_y, \cos\theta_z) = \frac{(RND1, RND2, RND3)}{\sqrt{RND1^2 + RND2^2 + RND3^2}}$$

Let $\Delta x, \Delta y,$ and Δz denote slab dimension or
plane spacing.

6-Sep-97

From this point of view ~~it~~ it doesn't matter
what position a ray is launched from, only
its direction, because launch position has
no impact on spacing between plane
strikes

Treat cants on surface perturbatively.

2 questions:

① How big do cants have to be to eliminate all parasitics?

② For a rectangular slab, how close to slab index does cladding index have to be to eliminate all parasitics.

   This question will be easiest to answer for a zero loss parasitic

set z face incident angle equal to $\theta_{crit z} = \sin^{-1}\left(\frac{1}{n_s}\right)$ and the x face hit and y face hit also $= \theta_{crit z} = \sin^{-1}\left(\frac{n_c}{n_s}\right)$

make this argument more rigorous!

Now work with direction cosines

$\theta_{c1} = \sin^{-1}\left(\frac{1}{n_s}\right)$

$\theta_{c2} = \sin^{-1}\left(\frac{n_c}{n_s}\right)$

$\cos\theta_{c1} = \frac{\sqrt{n_s^2 - 1}}{n_s}$

$\cos\theta_{c2} = \frac{\sqrt{n_s^2 - n_c^2}}{n_s}$

$\cos^2\theta_{c1} + 2\cos^2\theta_{c2} = 1$

$\frac{n_s^2 - 1}{n_s^2} + \frac{2(n_s^2 - n_c^2)}{n_s^2} = 1$

$$n_s^2 - 1 + 2n_s^2 - 2n_c^2 = n_s^2$$

$$2(n_s^2 - n_c^2) = 1$$

$$n_s^2 - n_c^2 = \frac{1}{2}$$

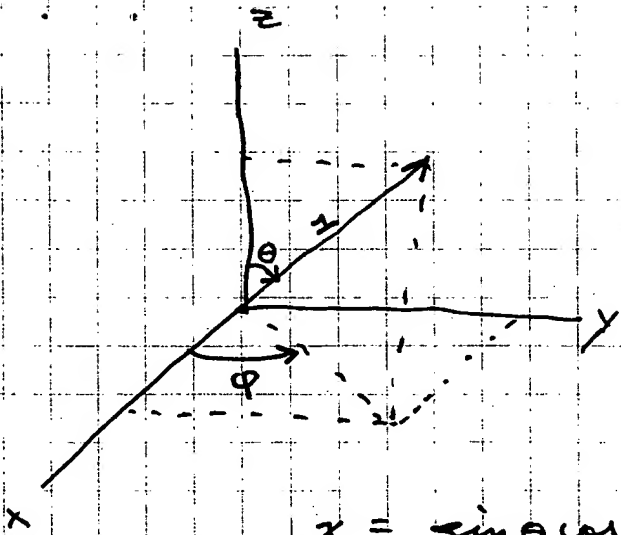when can this no longer be solved

$$n_c = \sqrt{n_s^2 - \frac{1}{2}}$$

$$n_c = \sqrt{1.682^2 - \frac{1}{2}} = \underline{1.677}$$

for $n_c > 1.677$ no zero loss parasitics exist!

(This agrees with
code: slab ASE 01.XCL
prediction.

Question 2 will be easier to answer numerically by finding the angular width over which a parasitic exists for given gain and cladding indices.

$$x = \sin\theta \cos\varphi = \cos\theta_x$$
$$y = \sin\theta \sin\varphi = \cos\theta_y$$
$$z = \cancel{\cos\theta\varphi} \overset{\cos\theta}{} = \cos\theta_z$$

$$\theta_x < \theta_{x\,crit}$$
$$\theta_y < \theta_{y\,crit}$$
$$\theta_z < \theta_{z\,crit}$$

to avoid 0-loss parasitics

$$\cos^2\theta_x + \cos^2\theta_y + \cos^2\theta_z = 1$$

$$\cos\theta_x > \cos\theta_{x\,crit}$$
$$\cos\theta_y > \cos\theta_{y\,crit}$$
$$\cos\theta_z > \cos\theta_{z\,crit}$$

to avoid 0-loss parasitics

$$\sin\theta_{x\,crit} = \frac{n_c}{n_s}$$
$$\sin\theta_{y\,crit} = \frac{n_c}{n_s}$$
$$\sin\theta_{z\,crit} = \frac{1}{n_s}$$

$$\cos\theta_x > \frac{\sqrt{n_s^2 - n_c^2}}{n_s}$$

$$\cos\theta_y > \frac{\sqrt{n_s^2 - n_c^2}}{n_s}$$

$$\cos\theta_z > \frac{\sqrt{n_s^2 - 1}}{n_s}$$

to avoid 0-loss parasiti

$$1 = \cos\theta_x^2 + \cos\theta_y^2 + \cos\theta_z^2 \quad \text{and this must be greater than}$$

$$1 > \frac{n_s^2 - n_c^2}{n_s^2} + \frac{n_s^2 - n_c^2}{n_s^2} + \frac{n_s^2 - 1}{n_s^2}$$

to avoid 0-loss parasiti

$$1 > \frac{3 n_s^2 - 2 n_c^2 - 1}{n_s^2}$$

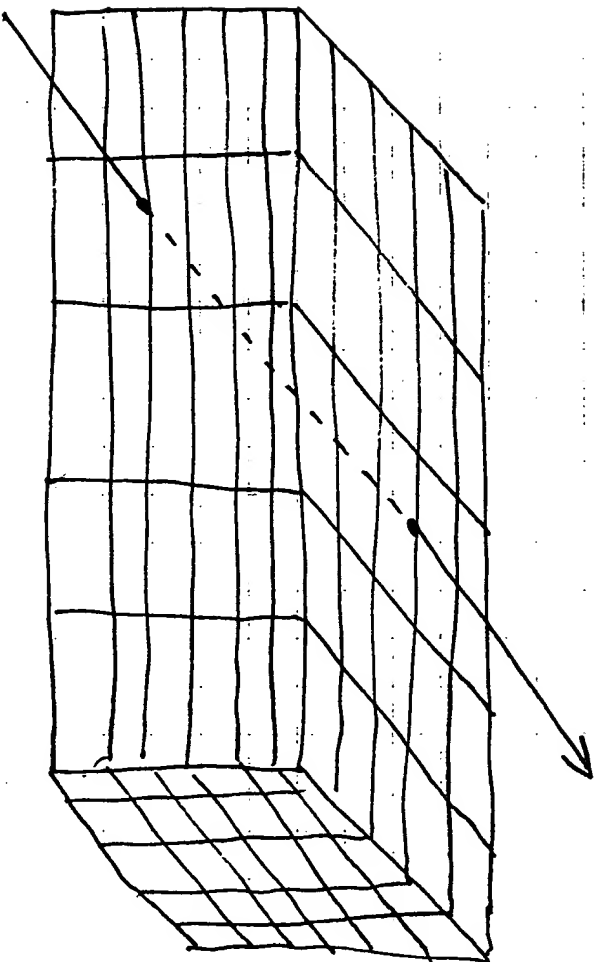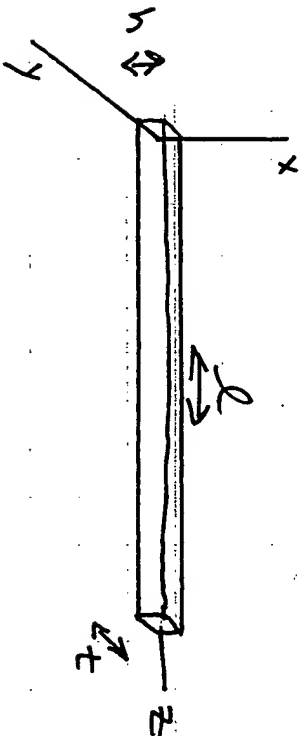$$n_s^2 > 3 n_s^2 - 2 n_c^2 - 1$$

$$1 > 2 (n_s^2 - n_c^2)$$

$$\frac{1}{2} > n_s^2 - n_c^2$$

$$n_c^2 > n_s^2 - \frac{1}{2}$$

$$n_c > \sqrt{n_s^2 - \frac{1}{2}} \; = \; \sqrt{1.82^2 - \frac{1}{2}} \; = \; 1.677$$

n_s is slab index

n_c is coating index

Parasitic propagation direction can be computed using a method of images construction

fill space using slab-unit-cell-images

- Define arbitrary ray direction using direction cosines
  $(\cos\theta_x, \cos\theta_y, \cos\theta_z)$

- gain of ray in given in neper/cm by

$$g = \frac{\ln(Ref_x)}{(l/\cos\theta_x)} \cdot \frac{\ln(Ref_y)}{(t/\cos\theta_y)} \cdot \frac{\ln(Ref_z)}{(t/\cos\theta_z)} \cdot \alpha$$

where: Ref_i is the reflection coefficient for i-oriented planes

α is slab specific gain coating

Zero-loss parasitics correspond to those may directions that are confined by TIR at all three sets of planes.

$$\left\{\begin{array}{l}\cos\theta_x < \cos\theta_{x\text{-crit}} = \dfrac{\sqrt{n_s^2 - n_c^2}}{n_s} \\[2mm] \cos\theta_y < \cos\theta_{y\text{-crit}} = \dfrac{\sqrt{n_s^2 - n_c^2}}{n_s} \\[2mm] \cos\theta_z < \cos\theta_{z\text{-crit}} = \dfrac{\sqrt{n_s^2 - 1}}{n_s}\end{array}\right.$$

TIR condition

where:
n_s = slab index
n_c = coating index

• Since $1 = \cos\theta_x^2 + \cos\theta_y^2 + \cos\theta_z^2$

$$1 < \frac{n_s^2 - n_c^2}{n_s^2} + \left(\frac{n_s^2 - n_c^2}{n_s^2}\right) + \frac{n_s^2 - 1}{n_s^2}$$

zero loss parasitics exist when

or

$$n_c < \sqrt{n_s^2 - \tfrac{1}{2}}$$

Zero-loss parasitics can be completely suppressed by choosing a cladding with refractive index large enough

$$n_c > \sqrt{n_s^2 - 1}$$